

SPECIFICATION

TITLE OF THE INVENTION

METHOD AND SYSTEM FOR PROCESSING A SEMI-CONDUCTOR DEVICE

5 BACKGROUND OF THE INVENTION

The present invention relates to a method and system for processing (producing) a semi-conductor device, and particularly to a technique for improving the accuracy of overlay at the mix-and-match exposure process in which different exposure tools are used for different layers on a semiconductor substrate.

In the recent trends of higher integration and enhanced functioning of semiconductor devices, the production process is required to be much more accurate for accomplishing these demands. On the other hand, reduction of the production cost of semiconductor devices is another crucial subject.

In the production process of a semiconductor device, circuit patterns formed on exposure masks (will be termed simply "masks") are transferred on to a semiconductor wafer (will be termed simply "wafer") which is coated with photo-resist by using a projection exposure tool (apparatus). As a semiconductor device is made circuit patterns on multiple layers, the circuit pattern of one layer is performed an exposure process, i.e., an overlap exposure process on to the circuit pattern of the lower layer in the state of that the circuit pattern of one layer is registered to the circuit pattern of the lower layer.

The production line of semiconductor devices has the installation of multiple projection exposure tools in general, and there exists the disparity of accuracy among these projection exposure tools. On this account, when the mix-and-match exposure, the so-called overlap exposure is carried out among multiple exposure tools, the disparity of accuracy among the exposure tools is generated error among layers called "matching error" in a product of the semiconductor device.

A scheme of preventing the matching error is using the same projection exposure tool throughout all steps of semiconductor device production process; however, it results in a lower operation efficiency of projection exposure tools and increased production cost.

Although the mix-and-match exposure has limited applications that allow certain ranges of matching error, the expansion of its application is demanded strongly from the viewpoint of cost reduction. Therefore, it is a crucial technique to correct the matching error in carrying out the mix-and-match exposure.

Japanese patent publication No. Hei 7-211627 discloses a method of optimized overlap exposure, which is based on the formulation of aberration curves of lenses of projection exposure tools in approximate functions, the calculation of correction factors from the disparity of functions, and the correction of exposure condition.

Another Japanese patent publication No. Hei 9-82607
discloses an exposure method which is based on the correction
of the overlay measurement result at exposure by using distortion
data of objective lens in each of machining numbers of each
5 exposure tool, and the adjustment of the projection magnification
factor and the rotation of the projected image.

Both of the above-mentioned prior arts are intended to
correct the entire exposure field of the exposure tools.

However, in the trends of higher integration and enhanced
10 functioning of semiconductor devices, when the mix-and-match
exposure is attempted without the investment for a huge facility
providing many exposure tools in the production line of
semiconductor devices, it is becoming difficult to keep the
matching error within the allowable range throughout the entire
15 exposure field.

What is crucial for semiconductor device products is the
accuracy of overlay in the device area (area where circuit patterns
for constructing semiconductor device are formed) where is
smaller than the exposure field. The above-mentioned prior arts
20 do not consider this affair.

SUMMARY OF THE INVENTION

With the intention of overcoming the foregoing problem,
it is an object of the present invention to provide a method
25 and system for processing a semi-conductor device which are

capable of improving the overlay accuracy of device area at the mix-and-match exposure process thereby to upgrade the yield and productivity of semi-conductor devices in the trends of higher integration and enhanced functioning of semiconductor devices.

5 In order to achieve the above objective, the inventive semiconductor device production method and system are designed to correct field distortions of the projection exposure tools used for the mix-and-match exposure process based on the calculation of the exposure distortion in the device area which is smaller than exposure fields specific to individual products 10 and individual exposing steps and the exposure distortion at the overlay measurement mark positions from device area. coordinate data, overlay measurement mark position data, and exposure field distortion data of the exposure tools, the calculation of a modification value which relates both exposure 15 distortions to each other, and the implementation of exposure by modifying with the modification value the exposure condition correction value which is calculated from the overlay measurement result. In consequence, it becomes possible to optimize the matching error correction in the device area based on the overlay measurement result.

The above-mentioned scheme can also correct formation errors of masks which are used for overlap exposure. Namely, the inventive semiconductor device fabrication method and system 25 are designed to calculate the exposure distortion of the device

area which is smaller than exposure fields specific to individual products and individual exposing steps and the exposure distortion at the overlay measurement mark positions from data of device area coordinates and overlay measurement mark positions and data of position error of the circuit pattern in the device area of masks used for overlap exposure and position error of the overlay measurement marks, calculate a modification value which relates both exposure distortions to each other, and carry out the exposure by modifying based on the modification value the exposure condition correction value which is calculated from the overlay measurement result.

By correcting both the field distortion data of the exposure tools and the mask forming error at the mix-and-match exposure process, the matching error can further be reduced. Namely, the inventive semiconductor device production method and system are designed to calculate the exposure distortion in the device area which is specific to each product and each exposing step and the exposure distortion at the overlay measurement mark positions from device area and overlay measurement mark position data, exposure field distortion data of the exposure tools used for mix-and-match exposure, and data of position error of the circuit pattern in the device area of the mask used for overlap exposure and position error of the overlay measurement marks of the mask, calculate a modification value which relates both exposure distortions to each other, and carry out the exposure

by modifying with the modification value the exposure condition correction value which is calculated from the overlay measurement result.

The inventive semiconductor device production method and system are designed to assess the overlay accuracy based on the measurement result of the overlay mark positions modified with the above-mentioned modification value. In consequence, it becomes possible to infer the overlay accuracy of device area from the measurement result of overlay measurement mark positions.

The inventive semiconductor device production system, which is designed to correct field distortions of exposure tools at the mix-and-match exposure process, includes a memory unit which stores data of the device area and overlay mark positions of exposure layers of a semiconductor device, a memory unit which stores the history of exposure of the layers of the semiconductor device, a memory unit which stores field distortion data of the exposure tools, and a memory unit which stores the measurement results provided by an overlay measurement tool. The system further includes an unit for searching for data of device area and overlay measurement mark positions of an exposure layer at the exposure process of the layer of the semiconductor device, an unit for searching for exposure field distortion data of the exposure tool used for the immediate exposure layer and the exposure tool used for the former exposure layer, a unit for

calculating the exposure distortion of the device areas in the immediate exposure layer and former exposure layer and the exposure distortion at the overlay measurement mark positions from the searched data of device area and overlay measurement mark positions and data of exposure field distortions of the exposure tool used for the immediate exposure layer and the exposure tool used for the former exposure layer, and an unit of calculating the difference between the immediate and former exposure layers of the calculated exposure distortions of the device area and the difference between the immediate and former exposure layers of the exposure distortions at the overlay measurement mark position thereby to evaluate a modification value which relates both differences to each other. The system further includes an unit for searching the overlay measurement results of the immediate and former exposure layers, an unit for calculating a first exposure condition correction value for the immediate exposure layer from the searched overlay measurement result, an unit for calculating a second exposure condition correction value by modifying the calculated first exposure condition correction value with the modification value, and an unit for releasing the calculated second exposure condition correction value.

These and other objects, features and advantages of the present invention will be apparent from the following description of preferred embodiments of invention taken in conjunction with

the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a brief block diagram showing the system construction based on a first embodiment of this invention;

Fig.2 is a brief block diagram showing the system construction based on a second embodiment of this invention;

Fig.3 is a brief block diagram showing the system construction based on a third embodiment of this invention;

Fig.4 is a brief block diagram showing the system construction based on a fourth embodiment of this invention;

Fig.5 is a flowchart used to explain the processes of the system shown in Fig.1;

Fig.6 is a flowchart used to explain the processes of the system shown in Fig.2;

Fig.7 is a flowchart used to explain the processes of the system shown in Fig.3;

Fig.8 is a diagram used to explain the parameters (first exposure condition correction values) which can be modified at the exposure process by the step-and-repeat exposure tool based on this invention;

Fig.9 is a diagram used to explain the parameters (first exposure condition correction values) which can be modified at the exposure process by the step-and-scan exposure tool based on this invention; and c

Fig.10 is a diagram showing the positional relation among the exposure field of the exposure tool based on this invention and the device area and overlay measurement marks of a semiconductor device.

5

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the method and system for processing (producing) a semiconductor device based on this invention will be explained with reference to the drawings.

In producing a semiconductor device according to this invention, photo-resist is applied to the surface of a wafer, and a circuit pattern which is formed on a mask is transferred by a projection exposure tool (apparatus) on to the photo-resist-coated wafer, thereby a pattern of the first layer is exposed. Next, a mask pattern of photo-resist is formed on the wafer by developing the exposed first-layer pattern. A circuit pattern is formed on the wafer according as the wafer, with the photo-resist mask pattern being formed thereon, is rendered the etching process.

Next, an interlayer insulation film is formed on the circuit pattern of the wafer, and a thin film layer of wiring film material for forming a circuit pattern of the second layer is formed after several processing steps. The wafer having the formation of the thin film layer of wiring film material is rendered another application of photo-resist, and overlap exposure based on

25

mix-and-match exposure for a second-layer circuit pattern is carried out by being overlaid to the first-layer circuit pattern.

The wafer, which has been rendered the overlap exposure, is developed to form a photo-resist mask pattern, and the second-layer circuit pattern which was overlaid on the first-layer circuit pattern is formed according as the thin film layer of wiring film material, with the photo-resist mask pattern being formed thereon, is rendered the etching process.

The following explains specifically the mix-and-match exposure process based on this invention.

First embodiment:

First of all, explanation will be given on the first embodiment of the apparatus (system) for conducting matching error compensation upon exposure field strain in the exposure tool according to the present invention, by referring to Figs. 1 and 5. In the figures, a reference numeral 31 is a host computer, in which various kinds of processing are executed. A reference numeral 32 is a product information database, holding and storing therein, design data such as device areas of the semiconductor device products and overlay measuring mark positions, etc., into which design information of the products (the semiconductor products) is inputted as the design information from a CAD system (not shown in the figure), for example, through a network 30.

A reference numeral 33 is a lot history database, holding and storing therein history data of indicating which one of the

projection exposure tools (apparatuses) and which one of the masks are used in each of the steps, and is inputted from a production line management system (not shown in the figure) for managing the production line, for example, through the network 30. Of course, the lot history database 33 may be inputted from each of the projection exposure tools (apparatuses) 21, 22, etc., through the network 30. However, since the management upon the history with respect to the semiconductor wafers is executed in the production line management system, it is preferable to input it/them from the production line management system, for example, through the network 30.

A reference numeral 34 is distortion database of each exposure tool indicating machining disparity (difference), holding and storing therein the measurement result of exposure field distortion indicative of the exposure distortion of the device area on each of the projection exposure tool (apparatus) (#1) 21 and the projection exposure tool (#2) 22. The distortion database of the projection exposure tools is stored exposure field distortion (calculated as grid shapes as shown in Fig.5 and Fig.7) indicating exposure distortion of device area acquired by following measurement method with inputting through an input means (not shown) or through the network 30. The measurement method comprises step of measuring coordinate positions of measurement reference patterns exposed them with each of the projection exposure tools (#1, #2) 21 and 22, by using a coordinate

measuring unit (not shown), or measuring overlay of patterns by the overlay measuring tool (apparatus) 23 when each of the exposure tools (#1, #2) 21 and 22 is overlay exposed a pattern on a reference pattern which was formed on a reference wafer and beforehand, was measured coordinate.

A reference numeral 36 is overlay measurement result database 36 holding and storing the measurement result 6 measured an intended object (wafer), e.g., selected based on the lot, type or name, by the overlay measuring tool 23. The intended object is exposure result which has been actually rendered the overlap exposure with reference to overlap measurement marks 43 in each of the exposure tools (#1, #2) 21 and 22 in the past. The overlay measurement result 6 for each of the exposure tools stored as the database 36 can obtain as data of an exposure field 41 shown in Fig. 10 by measuring the object with the overlay measuring tool 23, the object being the result of exposure overlay exposed with reference to the overlay measurement marks 43 by each exposure tool.

As mentioned above, the overlay measurement result 6 for each exposure tool indicates errors (e.g., shift, rotation, magnification factor, etc.) for the exposure field 41 with reference to the overlay measurement marks 43, the errors having in each exposure tool itself.

Therefore, a first exposure condition correction value 18 calculated on base of the overlay measurement result 6 as shown

in Fig. 5 is formed as an offset value (calibration value) of a shift, rotation, magnification factor, etc. for exposing the reference exposure field 50 with reference to the overlay measurement marks 43 shown in Fig.8 and Fig.9.

5 The exposure tools (#1, #2) 21 and 22 are used for the mix-and-match exposure process. These exposure tools (#1, #2) 21 and 22 and the overlay measuring tool 23 are all connected to the host computer 31 through the network 30. The host computer 31 may be designed to function as a modification value calculating unit, first exposure condition correction value calculating unit, and second exposure condition correction value calculating unit.

10 The first and second exposure condition correction value calculating unit may alternatively be included in the general controller of each exposure tool.

15 In carrying out the exposure on one layer of a semiconductor device, the host computer 31 searches the product information database 32 to get device area coordinate data and overlay measurement mark position data. The host computer 31 finds the exposure tool (#2) used for the one exposure layer (second layer) and the exposure tool (#1) used for the underlying exposure layer (former exposure layer, i.e., first exposure layer) based on the lot history database 33, and searches the exposure tool distortion database 34 to get exposure field distortion data (grid shapes) 2 and 1 as shown in Fig.5 of the found exposure tools (#1, #2) 21 and 22.

20

25

The host computer 31 calculates exposure distortions 13a and 11a of the device area of the immediate exposure layer (second layer) and the former exposure layer (first layer) and exposure distortions 14a and 12a at the overlay measurement mark positions from the exposure field distortion data 2 and 1 of the found exposure tools (#1, #2) 21 and 22 based on the product information 3 (device area coordinate data and overlay measurement mark position data) taken out of the product information database 32, as shown in Fig.5.

If the device area 42 is within the exposure field 41 of the exposure tool (#2) 22 as shown in Fig.10, the exposure distortion 13a of the device area of the second layer shown in Fig.5 can readily be calculated from the exposure field distortion data 2 of the exposure tool (#2) 22 based on the device area coordinate data. Similarly, if the device area 42 is within the exposure field 41 of the exposure tool (#1) 21 as shown in Fig.10, the exposure distortion 11a of the device area of the first layer shown in Fig.5 can readily be calculated from the exposure field distortion data 1 of the exposure tool (#1) 21 based on the device area coordinate data.

As the positions of measurement of the exposure field distortion 2 of the exposure tool (#2) 22 do not necessarily coincide with the overlay measurement mark positions, the exposure distortion 14a at the overlay measurement mark positions of the second layer can be readily calculated by interpolating

the exposure field distortion data 2 of the exposure tool (#2) 22 based on the overlay measurement mark position data.

Similarly, as the positions of measurement of the exposure field distortion 1 of the exposure tool (#1) 21 do not necessarily coincide with the overlay measurement mark positions, the exposure distortion 12a at the overlay measurement mark positions of the first layer can be readily calculated by interpolating the exposure field distortion data 1 of the exposure tool (#1) 21 based on the overlay measurement mark position data.

As a result of the foregoing calculation of the host computer 31, the exposure distortion 13a of the second-layer device area and exposure distortion 14a at the second-layer overlay measurement mark positions caused by the exposure tool (#2) 22, and the exposure distortion 11a of the first-layer device area and exposure distortion 12a at the first-layer overlay measurement mark positions caused by the exposure tool (#1) 21 are stored in a memory 38.

Next, the host computer 31 evaluates the differences of the exposure distortion 13a of the second-layer device area and the exposure distortion 14a of the second-layer overlay measurement mark positions caused by the exposure tool (#2) 22 from the exposure distortion 11a of the first-layer device area and the exposure distortion 12a of the first-layer overlay measurement mark positions caused by the exposure tool (#1) 21 by reading out the distortion data from the memory 38 thereby

to calculate the matching error 15a of the device area and matching error 16a of the overlay measurement mark positions indicative of the disparity between the exposure tool (#1) 21 and the exposure tool (#2) 22 shown in Fig.5, and saves the calculation result in the memory 38.

The reason for the separation of the matching error 15a of device area and the matching error 16a of overlay measurement mark positions for the assessment of the difference of exposure distortions (matching error) between the exposure tool (#1) 21 and the exposure tool (#2) 22 is that the exposure distortion differs at positions inside the device area and at overlay measurement mark positions located in the periphery of device area, and that the exposure distortion is greater at the overlay measurement mark positions than inside the device area, while the present invention is intended to reduce drastically the matching error 15a in the device area.

It is also possible for the host computer 31 to display the matching error 15a of device area and matching error 16a of overlay measurement mark positions as the difference of exposure distortions (matching error) indicating machining difference between the exposure tool (#1) 21 and the exposure tool (#2) 22, on a display unit 39.

Next, the host computer 31 calculates each of correction parameters (e.g., shift, rotation, magnification factor, etc.) for the matching error 15a of device area and matching error

16a of overlay measurement mark positions saved in the memory 38. These correction parameters are linear, and the disparity between the exposure tools in terms of the relation of the matching error of device area to the matching error of overlay measurement mark positions is calculated as a modification value (shift, rotation, magnification factor, etc.) 17a by simply taking differences by the following formula (1) through (3) and stored in the memory 38. It is also possible for the host computer 31 to display the stored modification value (shift, rotation, magnification factor, etc.) 17a on the display unit 39.

It becomes possible for the host computer 31 to provide the exposure tool (#2) 22 for the second layer, for example, with the modification value (shift, rotation, magnification factor, etc.) 17a indicating the machining difference between the exposure tools in the device area for the overlay measurement mark positions, stored in the memory 38 through the network 30, so that the exposure tool (#2) 22 calculates the second exposure condition correction value 19a by modifying the first exposure condition correction value 18 with the modification value 17a.

Modification value (shift) = (shift of device area) - (shift at overlay measurement mark positions) ... (1)

Modification value (rotation) = (rotation of device area) - (rotation at overlay measurement mark positions) ... (2)

Modification value (magnification factor) = (magnification factor of device area) - (magnification factor at overlay

measurement mark positions) ... (3)

Next, the manner of calculation of the first exposure condition correction value 18 implemented by the host computer 31 or the exposure tool (#1) 21 or (#2) 22 based on the overlay measurement result 6 which is derived from the actual exposure by positioning with reference to the overlay measurement marks by the exposure tools 21 and 22 will be explained. The overlay measurement result 6 is obtained from the overlay measuring unit 23 by measuring the object (wafer) which has been rendered the exposure by being positioned with reference to the overlay measurement marks by the exposure tools (#1, #2) 21 and 22, and it is stored in the overlay measurement result database 36 through the network 30. Accordingly, it is also possible to provide the exposure tools (#1, #2) 21 and 22 through the network 30 with the overlay measurement result 6 which is the actual exposure result (actual exposure result based on the positioning with reference to the overlay measurement marks) stored in the overlay measurement result database 36.

The host computer 31 or the exposure tool (#2) 22 calculates the first exposure condition correction values 18 based on the overlay measurement result 6 which is the result of actual exposure by the exposure tool (#2) 22 by positioning with reference to the overlay measurement marks. The first exposure condition correction value 18 is an offset value (calibration value) of the shift, rotation, magnification factor, etc. for exposing

the reference exposure field 50 shown in Fig.8 and Fig.9 with reference to the overlay measurement marks 43 by the exposure tool (#2) 22.

Next, the exposure condition correcting parameter for
 5 correcting the error inherent to each exposure tool (error of exposure with reference to the overlay measurement marks 43 with respect to the reference exposure field 50) will be explained in connection with Fig.8 and Fig.9. Fig.8 shows exposure condition correcting parameters used by the step-and-repeat
 10 exposure tool. In the figure, indicated by 50 is the reference position of the exposure field 41 on the case of normal exposure. Indicated by 51 is a shifted exposure field 41 resulting from the actual exposure with reference to the overlay measurement
 15 marks 43, and it can be corrected by shifting the wafer stage of the exposure tool in the x direction (Shift-X) and y direction (Shift-Y).

Indicated by 52 is a exposure field 41 rotated by angle
 θ resulting from the actual exposure with reference to the overlay measurement marks 43, and it can be corrected by turning
 20 the wafer stage or mask stage of the exposure tool. Indicated by 53 is the exposure field 41 resulting from the actual exposure with reference to the overlay measurement marks 43 of the case of erroneous magnification factor, and it can be corrected by adjusting the magnification factor of the objective lens of
 25 exposure tool.

Fig.9 shows exposure condition correcting parameters used by the step-and-scan exposure tool. The shift and rotation of exposure field are the same as explained on Fig.8. Indicated by 54 is the result of actual exposure with reference to the overlay measurement marks 43 with different magnification factors of the exposure field 41 in the x direction (Mag-X) and y direction (Mag-Y). The step-and-scan exposure tool can correct this deformation by adjusting the magnification factor of the objective lens and the scanning distance. Indicated by 55 is a skew exposure field 41 resulting from the actual exposure with reference to the overlay measurement marks 43, and it can be corrected by inclining the scanning direction.

As mentioned above, the host computer 31 or the exposure tool (#2) 22 calculates the first exposure condition correction value 18 based on the measurement result 6 of the past stored in the overlay measurement result database 36, and stores in the memory 38. Next, the host computer 31 or the exposure tool (#2) 22 calculates the second exposure condition correction value 19 for optimizing the overlap of device area by the exposure tool (#2) 22 as a sum of the foregoing first exposure condition correction value 18 and the modification value 17a (matching error indicative of the disparity of exposure tools in the device area with respect to the overlay measurement mark positions) by the following formulas (4) through (6).

Second exposure condition correction value (shift) = First

exposure condition correction value (shift) + modification value
(shift) ... (4)

Second exposure condition correction value (rotation) = First
exposure condition correction value (rotation) + modification
5 value (rotation) ... (5)

Second exposure condition correction value (magnification
factor) = First exposure condition correction value
(magnification factor) + modification value (magnification
factor) ... (6)

10 The calculated second exposure condition correction value
19a is fed to the controller of the exposure tool (#2) 22, which
then carries out the exposure of the second layer under the
calibration correction control with reference to the overlay
measurement marks 43 by the controller, and it becomes possible
15 to carry out the mix-and-match exposure with the optimized overlap
in the device area 42.

The exposure field distortion of exposure tool varies
depending on the position in the exposure field, and the overlay
accuracy measured based on the overlay measurement marks is not
20 necessarily consistent with the overlay accuracy of device area.
The exposure field distortions of exposure tools are invariable,
although they are specific to individual exposure tools. These
distortions are measured in advance as data 1 and 2, and the
exposure distortions 12a and 14a at the overlay measurement marks
25 and exposure distortions 11a and 13a of the device area are

predicted by calculation from the data 1 and 2 thereby to evaluate the matching error 16a at the overlay measurement marks and the matching error 15a of the device area. The exposure condition correction value 18 derived from the overlay measurement result 5 6 is modified based on these matching errors, and in consequence it becomes possible to optimize the matching error correction in the device area 42 even in the case of carrying out the mix-and-match exposure with different exposure tools for different layers on a substrate.

4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022 1023 1024 1025 1026 1027 1028 1029 1030 1031 1032 1033 1034 1035 1036 1037 1038 1039 1040 1041 1042 1043 1044 1045 1046 1047 1048 1049 1050 1051 1052 1053 1054 1055 1056 1057 1058 1059 1060 1061 1062 1063 1064 1065 1066 1067 1068 1069 1070 1071 1072 1073 1074 1075 1076 1077 1078 1079 1080 1081 1082 1083 1084 1085 1086 1087 1088 1089 1090 1091 1092 1093 1094 1095 1096 1097 1098 1099 1100 1101 1102 1103 1104 1105 1106 1107 1108 1109 1110 1111 1112 1113 1114 1115 1116 1117 1118 1119 1120 1121 1122 1123 1124 1125 1126 1127 1128 1129 1130 1131 1132 1133 1134 1135 1136 1137 1138 1139 1140 1141 1142 1143 1144 1145 1146 1147 1148 1149 1150 1151 1152 1153 1154 1155 1156 1157 1158 1159 1160 1161 1162 1163 1164 1165 1166 1167 1168 1169 1170 1171 1172 1173 1174 1175 1176 1177 1178 1179 1180 1181 1182 1183 1184 1185 1186 1187 1188 1189 1190 1191 1192 1193 1194 1195 1196 1197 1198 1199 1200 1201 1202 1203 1204 1205 1206 1207 1208 1209 1210 1211 1212 1213 1214 1215 1216 1217 1218 1219 1220 1221 1222 1223 1224 1225 1226 1227 1228 1229 1230 1231 1232 1233 1234 1235 1236 1237 1238 1239 1240 1241 1242 1243 1244 1245 1246 1247 1248 1249 1250 1251 1252 1253 1254 1255 1256 1257 1258 1259 1260 1261 1262 1263 1264 1265 1266 1267 1268 1269 1270 1271 1272 1273 1274 1275 1276 1277 1278 1279 1280 1281 1282 1283 1284 1285 1286 1287 1288 1289 1290 1291 1292 1293 1294 1295 1296 1297 1298 1299 1300 1301 1302 1303 1304 1305 1306 1307 1308 1309 1310 1311 1312 1313 1314 1315 1316 1317 1318 1319 1320 1321 1322 1323 1324 1325 1326 1327 1328 1329 1330 1331 1332 1333 1334 1335 1336 1337 1338 1339 1340 1341 1342 1343 1344 1345 1346 1347 1348 1349 1350 1351 1352 1353 1354 1355 1356 1357 1358 1359 1360 1361 1362 1363 1364 1365 1366 1367 1368 1369 1370 1371 1372 1373 1374 1375 1376 1377 1378 1379 1380 1381 1382 1383 1384 1385 1386 1387 1388 1389 1390 1391 1392 1393 1394 1395 1396 1397 1398 1399 1400 1401 1402 1403 1404 1405 1406 1407 1408 1409 1410 1411 1412 1413 1414 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426 1427 1428 1429 1430 1431 1432 1433 1434 1435 1436 1437 1438 1439 1440 1441 1442 1443 1444 1445 1446 1447 1448 1449 1450 1451 1452 1453 1454 1455 1456 1457 1458 1459 1460 1461 1462 1463 1464 1465 1466 1467 1468 1469 1470 1471 1472 1473 1474 1475 1476 1477 1478 1479 1480 1481 1482 1483 1484 1485 1486 1487 1488 1489 1490 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526 1527 1528 1529 1530 1531 1532 1533 1534 1535 1536 1537 1538 1539 1540 1541 1542 1543 1544 1545 1546 1547 1548 1549 1550 1551 1552 1553 1554 1555 1556 1557 1558 1559 1560 1561 1562 1563 1564 1565 1566 1567 1568 1569 1570 1571 1572 1573 1574 1575 1576 1577 1578 1579 1580 1581 1582 1583 1584 1585 1586 1587 1588 1589 1590 1591 1592 1593 1594 1595 1596 1597 1598 1599 1600 1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613 1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626 1627 1628 1629 1630 1631 1632 1633 1634 1635 1636 1637 1638 1639 1640 1641 1642 1643 1644 1645 1646 1647 1648 1649 1650 1651 1652 1653 1654 1655 1656 1657 1658 1659 1660 1661 1662 1663 1664 1665 1666 1667 1668 1669 1670 1671 1672 1673 1674 1675 1676 1677 1678 1679 1680 1681 1682 1683 1684 1685 1686 1687 1688 1689 1690 1691 1692 1693 1694 1695 1696 1697 1698 1699 1700 1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713 1714 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726 1727 1728 1729 1730 1731 1732 1733 1734 1735 1736 1737 1738 1739 1740 1741 1742 1743 1744 1745 1746 1747 1748 1749 1750 1751 1752 1753 1754 1755 1756 1757 1758 1759 1760 1761 1762 1763 1764 1765 1766 1767 1768 1769 1770 1771 1772 1773 1774 1775 1776 1777 1778 1779 1780 1781 1782 1783 1784 1785 1786 1787 1788 1789 1790 1791 1792 1793 1794 1795 1796 1797 1798 1799 1800 1801 1802 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 1813 1814 1815 1816 1817 1818 1819 1820 1821 1822 1823 1824 1825 1826 1827 1828 1829 1830 1831 1832 1833 1834 1835 1836 1837 1838 1839 1840 1841 1842 1843 1844 1845 1846 1847 1848 1849 1850 1851 1852 1853 1854 1855 1856 1857 1858 1859 1860 1861 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659

correction of exposure condition for each semiconductor product even in the case of carrying out the mix-and-match exposure. Since the exposure field distortion of exposure tool is large in the edge section of exposure field, the effect of accuracy improvement will increase by the matching error correction in the device area excluding the edge section.

Following the correction of exposure condition in this manner, the exposure tool (#2) 22 is used to carry out the exposure of the second layer, and the exposure of high overlay accuracy, i.e., smaller matching error with respect to the first-layer exposure pattern, in the device area can be accomplished across the whole wafer surface.

Second embodiment:

Next, the second embodiment of invention which pertains to a system for matching error correction for the masks fitted to the exposure tools will be explained with reference to Fig.2 and Fig.6.

This embodiment differs from the first embodiment in that a mask accuracy database 35 which stores patterns of device area on the masks and the measurement result of position error of overlay measurement marks is installed in place of the exposure tool distortion database 34. In carrying out the exposure of one layer (second layer) of a semiconductor device, the host computer 31 searches the mask accuracy database 35 to get data 5 and 4 of patterns of device area and position error of overlay

measurement marks of the mask to be used for the immediate layer (second layer) and the mask which has been used for the former layer (first layer) based on the coordinate data of the device area 42 and position data of the overlay measurement marks 43 taken out as product information 3 from the product information database 32 based on the kind (type/name) of the semiconductor device to be processed, as shown in Fig.6. The host computer 31 calculates the exposure distortions 13b and 11b of the device area and exposure distortions 14b and 12b at the overlay measurement mark positions of the second and first layers from the taken-out data 5 and 4.

The host computer 31 calculates the matching error 15b of the device area indicative of the disparity of masks in the device area based on the calculated exposure distortion 13b of the device area of the second layer and the exposure distortion 11b of the device area of the first layer, calculates the matching error 16b at the overlay measurement mark positions indicative of the disparity of masks at the overlay measurement mark positions based on the exposure distortion 14b at the overlay measurement mark positions of the second layer and the exposure distortion 12b at the overlay measurement mark positions of the first layer, and calculates the modification values (matching errors) 17b indicative of the disparity of masks in the device area with respect to the overlay measurement mark positions and indicative of the relation between the calculated matching errors 15b and

16b.

The host computer 31 searches the overlay measurement result database 36 to get the overlay measurement result 6 of the exposure tool (#2) 22 which has the mask (#2) for the exposure of the second layer, and calculates the first exposure condition correction value (offset value, e.g., shift, rotation, magnification factor, etc.) 18 for the exposure of the reference exposure field 50 based on the taken-out overlay measurement result 6, as in the case of the first embodiment. Next, the host computer 31 calculates a second exposure condition correction value 19b by modifying the calculated first exposure condition correction value 18 with the modification value (matching error) 17b indicative of the disparity of masks in the device area with respect to the overlay measurement mark positions, and delivers the second exposure condition correction value 19b to the exposure tool (#2) 22 which carries out the exposure of the second layer.

The exposure tool (#2) 22 modifies the exposure condition with the second exposure condition correction value 19b, and thereafter carries out the exposure of the second layer of the semiconductor device.

In consequence, it becomes possible to arrange the system which carries out automatically the processes shown in Fig.6. In the figure, indicated by 4 is the position error of the circuit pattern in the device area and the position error of the overlay

measurement marks on the mask used for the exposure of the first layer, and 5 is the position error of the circuit pattern in the device area and the position error of the overlay measurement marks on the mask used for the exposure of the second layer.

5 These position errors 4 and 5 can be obtained by measuring the pattern and marks on the mask with the coordinate measuring unit and comparing the measured values with the design data. The position error of the circuit pattern in the device area may be either based on the measurement of the actual device pattern or based on the measurement of a dummy pattern which is placed
10 in the device area. The subsequent processes are the same as explained on Fig.5.

The host computer 31 gets the exposure distortions
15 (11b, 12b, 13b, 14b) caused by the mask from the product information 11 and the position errors 4 and 5 of the mask, calculates the matching error 15b (of the mask) in the device area and the matching error 16b (of the mask) at the overlay measurement mark positions, and takes the difference of correction parameters to evaluate a modification value 17b. The host computer 31 or the exposure
20 tool (#2) 22 calculates the second exposure condition correction value 19b by modifying the first exposure condition correction value 18, which is calculated from the past overlay measurement result 6 of the exposure tool (#2) 22 having the mask #2, with the modification value 17b, and sets the calculated second
25 exposure condition correction value 19b to the exposure tool

(#2) 22 having the mask #2 and carries out the exposure.

The exposure field distortions caused by the masks are invariable, although they are specific to individual masks. These distortions are measured in advance as data 4 and 5, and the exposure distortions 12b and 14b at the overlay measurement marks and exposure distortions 11b and 13b of the device area are predicted by calculation from the data 4 and 5 thereby to evaluate the matching error 16b at the overlay measurement marks and the matching error 15b of the device area. The exposure condition correction value 18 derived from the overlay measurement result 6 is modified with these matching errors, and in consequence it becomes possible to optimize the matching error correction in the device area 42 even in the case of carrying out the mix-and-match exposure by use of different masks for different layers on the substrate.

Third embodiment:

Next, the third embodiment of invention which pertains to a system for matching error correction against the exposure field distortion of exposure tools and the masks fitted to the exposure tools will be explained with reference to Fig.3 and Fig.7. This embodiment combines the first and second embodiments for dealing with the disparity among the masks as well as among the exposure tools encountered in the mix-and-match exposure.

Fig.3 explains the system of implementing the matching error correction against the exposure field distortion of exposure

tools and the masks. This embodiment differs from the first and second embodiments in that it includes both the exposure tool distortion database 34 shown in Fig.1 and the mask accuracy database 35 shown in Fig.2. In carrying out the exposure of one exposure layer (second layer) of a semiconductor device, as shown in Fig. 7, the host computer 31 searches the exposure tool distortion database 34 to get exposure field distortion data 2 and 1 of the exposure tool (#2) 22 used for the immediate layer (second layer) and the exposure tool (#1) 21 used for the former layer (first layer) based on the coordinate data of the device area 42 and the position data of the overlay measurement marks 43 taken out as product information 3 from the product information database 32 based on the kind (type/name) of the semiconductor device to be processed, and further searches the mask accuracy database 35 to get data 5 and 4 of the pattern of device area and position error of the overlay measurement marks used for the immediate layer (second layer) and the mask used for the former layer (first layer).

The host computer 31 calculates the exposure distortion 13c of the device area and the exposure distortion 14c at the overlay measurement mark positions of the exposure layer (second layer) from the taken-out data 2 and 5, and calculates the exposure distortion 11c of the device area and the exposure distortion 12c at the overlay measurement mark positions of the former exposure layer (first layer) from the taken-out data 1 and 4.

The host computer 31 further calculates the matching error 15c of device area indicative of the disparity among the exposure tools and masks in the device area based on the calculated exposure distortion 13c in the device area of the second layer and the exposure distortion 11c in the device area of the first layer, and calculates the matching error 16c at the overlay measurement mark positions indicative of the disparity among the exposure tools and masks based on the calculated exposure distortion 14c at the overlay measurement mark positions of the second layer and the exposure distortion 12c at the overlay measurement mark positions of the first layer.

The host computer 31 calculates a modification value (matching error indicative of the disparity among the exposure tools and masks in the device area with respect to the overlay measurement mark positions) 17c which relates both matching errors (matching errors in the device area and at overlay measurement mark positions) 15c and 16c to each other.

Following the correction of exposure condition, the exposure tool (#2) 22 is used to carry out the exposure of the second layer, and the exposure of high overlay accuracy, i.e., smaller matching error with respect to the first-layer exposure pattern, in the device area can be accomplished across the whole wafer surface.

The host computer 31 searches the overlay measurement result database 36 to get the overlay measurement result 6 of the exposure

tool (#2) 22 which is about to carry out the exposure of the second layer, and calculates a first exposure condition correction value (offset value, e.g., shift, rotation, magnification factor, etc.) 18 for the exposure of the reference exposure field 50 based on the taken-out overlay measurement result 6, as in the cases of the first and second embodiments.

Next, the host computer 31 calculates a second exposure condition correction value 19c by modifying the calculated first exposure condition correction value 18 with the modification value (matching error) 17c indicative of the disparity among the exposure tools and masks in the device area with respect to the overlay measurement mark positions, and delivers the second exposure condition correction value 19c to the exposure tool (#2) 22 which carries out the exposure of the second layer.

The exposure tool (#2) 22 modifies the exposure condition with the second exposure condition correction value 19c, and thereafter carries out the exposure of the second layer of the semiconductor device.

In consequence, it becomes possible to arrange the system which carries out automatically the processings shown in Fig. 7. In this case, the exposure distortions (11c, 12c, 13c, 14c) are sums of the exposure field distortions (1, 2) and mask position errors (4, 5). Although the measurement positions of exposure field distortion and the measurement positions of mask position error do not necessarily coincide, it is possible to calculate

the sum of the exposure field distortion and the mask position error of the same positions based on the interpolation of one set of positions.

The subsequent processes are the same as explained on Fig.5 and Fig.6. The host computer 31 calculates the matching error 15c of the device area and the matching error 16c at the overlay measurement mark positions from the exposure distortions (11c,12c,13c,14c), and takes the difference of correction parameters to evaluate a modification value (matching error) 17c indicative of the disparity among the exposure tools and masks in the device area with respect to the overlay measurement mark positions.

The host computer 31 calculates a second exposure condition correction value 19c by modifying the first exposure condition correction value 18, which is calculated from the overlay measurement result 6, with the modification value 17c, and sets the calculated second exposure condition correction value 19c to the exposure tool (#2) 22 to carry out the exposure.

The exposure field distortions caused by the exposure tools and masks are invariable, although they are specific to individual exposure tools and masks. These distortions are measured in advance as data 1,2,4 and 5, and the exposure distortions 12c and 14c at the overlay measurement marks and exposure distortions 11c and 13c of the device area are predicted by calculation from the data 1,2,4 and 5 thereby to evaluate the matching error 16c

at the overlay measurement marks and the matching error 15c of the device area. The exposure condition correction value 18 derived from the overlay measurement result 6 is modified with these matching errors, and in consequence it becomes possible to optimize the matching error correction in the device area 42 even in the case of carrying out the mix-and-match exposure by use of different exposure tools and masks for different layers on the substrate.

Following the correction of exposure condition, the exposure tool (#2) 22 is used to carry out the exposure of the second layer, and the exposure of high overlay (registration) accuracy, i.e., smaller matching error with respect to the first-layer exposure pattern, in the device area can be accomplished across the whole wafer surface.

Fourth embodiment:

Next, the fourth embodiment of invention which pertains to a system for matching error correction against the exposure field distortion of exposure tools and the masks fitted to the exposure tools will be explained with reference to Fig.4. The figure explains the system which implements the assessment of overlay based on the assessment value for the device area. An overlay criterion database 37 stores overlay criterion (control limit) values of semiconductor devices.

The host computer 31 searches the exposure tool distortion database 34 to get exposure field distortion data 2 and 1 of

the exposure tool (#2) 22 used for the immediate layer (second layer) and the exposure tool (#1) 21 used for the former layer (first layer) based on the coordinate data of the device area 42 and the position data of the overlay measurement marks 43 taken out as product information 3 from the product information database 32 based on the kind of the semiconductor device to be processed, and further searches the mask accuracy database 35 to get data 5 and 4 of the pattern of device area and position error of the overlay measurement marks used for the immediate layer (second layer) and the mask used for the former layer (first layer), in the same manner as the third embodiment.

The host computer 31 calculates the exposure distortion 13c of the device area and the exposure distortion 14c at the overlay measurement mark positions of the exposure layer (second layer) from the taken-out data 2 and 5, and calculates the exposure distortion 11c of the device area and the exposure distortion 12c at the overlay measurement mark positions of the former exposure layer (first layer) from the taken-out data 1 and 4.

The host computer 31 further calculates the matching error 15c of the device area indicative of the disparity among the exposure tools and masks in the device area based on the calculated exposure distortion 13c of the device area of the second layer and the exposure distortion 11c of the device area of the first layer, and calculates the matching error 16c at the overlay measurement mark positions indicative of the disparity among

the exposure tools and masks based on the calculated exposure distortion 14c at the overlay measurement mark positions of the second layer and the exposure distortion 12c at the overlay measurement mark positions of the first layer. The host computer 31 calculates a modification value 17c which relates both matching errors 15c and 16c to each other.

Furthermore, in this embodiment, the host computer 31 or the exposure tool (#2) 22 calculates an inferred value of overlay in the device area from the modification value 17c by modifying directly the matching error of the exposure field 41 resulting from the actual exposure measured by the overlay measuring tool 23, and stores the calculated inferred value of overlay of device area as an assessment value of overlay in the memory 38 or a memory of the exposure tool (#2) 22. In consequence, it becomes possible to display as an assessment value the inferred error of overlapping in the device area at the exposure process of the second layer with the exposure tool (#2) 22 over the first layer on the display unit 39 or a display screen of the exposure tool (#2) 22. The modification value 17c may be displayed at the same time on the display unit 39 or the display screen of the exposure tool (#2) 22.

The host computer 31 or the exposure tool (#2) 22 further searches the overlay criterion database 37 depending on the kind (type/name) and processing step of the semiconductor product to get the overlay criterion value of device area in the immediate

processing step of the semiconductor product, compares the taken-out overlay criterion value of device area with the criterion value which has been calculated and stored previously thereby to judge the approval of overlay (registration), and stores the result in the memory 38 or the memory of the exposure tool (#2) 22. The judgment result of overlapping of device area resulting from the exposure of the second layer over the first layer is displayed on the display unit 39 or the display screen of the exposure tool (#2) 22, or sent through the network 30 and displayed on a display unit of the production line management system, so that further modification or the selection of a proper exposure tool or mask is made possible.

In consequence, it becomes possible to accomplish a system which carries out automatically the judgment of overlapping, which is much closer to the performance of semiconductor device product than using the result of measurement of the overlay measurement marks (outside of device area).

The first through third embodiments are intended to optimize the overlay of device area for the mix-and-match exposure process based on the prior calculation of the matching errors 15 and 16 caused by the disparity among the exposure tools in the device area and mark positions, the evaluation of the modification value 17 which indicates their relation, and the correction of the exposure condition 18, which is calculated from the overlay measurement result 6, with the modification value 17.

According to the fourth embodiment, in which the overlay measurement result 6 is modified directly with the modification value 17, it is possible to infer the overlay accuracy of device area based on the overlay measurement result 6. With the inferred value being used as assessment value, it becomes possible to implement the assessment of overlay more practically than using the measurement result of overlay measurement marks (outside of device area). For example, based on the comparison between the overlay criterion value of device area and the assessment value, the judgment of approval of overlay can be much closer to the performance of semiconductor device product.

According to the present invention, the modification value of exposure condition is calculated in correspondence to the exposure field range which differs depending on each product and the overlay measurement mark positions which differ depending on each product and processing step based on field distortion data of each exposure tool, and the exposure condition correction value resulting from the overlay measurement result is modified with the modification value, and in consequence it is possible to improve the overlay accuracy of device area at the mix-and-match exposure process and improve the yield and productivity of semiconductor devices.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof.

The present embodiment is therefore to be considered in all

respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

WHAT IS CLAIMED IS:

1. A method of processing a semiconductor device comprising the steps of:

applying photo-resist to the surface of a substrate to be processed;

rendering exposure of a first overlay measurement mark and a first pattern to the substrate coated with the photo-resist by using a first exposure tool which is fitted up with a first mask;

processing the substrate, which has been rendered the exposure of the first pattern, to form thereon a first overlay measurement mark and a first circuit pattern;

applying photo-resist to the substrate surface on which the first overlay measurement mark and first circuit pattern have been formed;

rendering the exposure of a second overlay measurement mark and a second pattern to the substrate coated with the photo-resist by using a second exposure tool which is fitted up with a second mask;